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Design and Analysis of Dual Side Shaper Using Scotch Yoke Mechanism

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ABSTRACT: This paper describes about **dual side shaper machine using a scotch yoke mechanism** which can be used in industries for cutting process. A Shaper is a machine used for shaping (metal removal) operation on the work piece. A usual shaper machine operates by a principle of whitworth quick return mechanism where materials are processed at one end and other end remains idle. But in a dual side shaper machine, materials are processed at both ends which become advantageous when compared to usual shaper. Nowadays, Industries try to achieve high production rate at a minimal amount of time, cost etc. Usage of dual side shaper machine eliminates most disadvantages faced by a single side shaper. The main advantage of dual side shaper is that it decreases time as well as production cost. Thereby it increases productivity. Another advantage is that number of moving parts is less when compared to usual machine. This model uses a single power source which can be connected to gears for increasing or decreasing the speed of cut.

KEYWORDS: Construction, Working, Detailed view, Shaper Calculations, Analysis.

I.INTRODUCTION

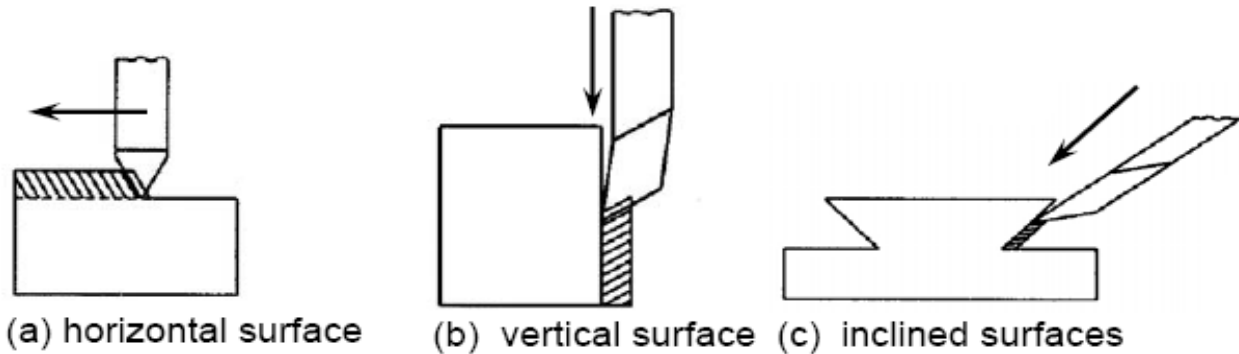
A **Shaper** is a type of machine tool that uses linear relative motion between the work piece and a single-point cutting tool to machine a linear tool path. Its cut is analogous to that of a lathe, except that it is linear instead of helical. The work piece mounts on a rigid, box-shaped table in front of the machine. The height of the table can be adjusted to suit the work piece, and the table can traverse sideways underneath the reciprocating tool, which is mounted on the ram. Table motion may be controlled manually, but is usually advanced by automatic feed mechanism acting on the feed screw. The ram slides back and forth above the work. At the front end of the ram is a vertical tool slide that may be adjusted to either side of the vertical plane along the stroke axis. This tool-slide holds the clapper box and tool post, from which the tool can be positioned to cut a straight, flat surface on the top of the work piece. The tool-slide permits feeding the tool downwards to deepen a cut. The tool-slide permits feeding the tool downwards to deepen a cut. When a load is placed on the input rod of the scotch yoke by an actuator, sideward thrust causes the input rod and yoke arm to bow and twist. This increases the friction on the sliding nut. At the extreme positions of travel of the sliding nut, the bowing and twisting become severe and the yoke arm tends to bind. Diagrammatic representation of tool feed direction is shown below:

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Vol. 6, Issue 7, July 2017



II.CONSTRUCTION

Sr. No	Part Description	Material	Dimensions
1	Frame is a rigid body that supports the entire mechanism.	Mild steel tubes- rectangular Cross section	Base 450mm X 300mm
2	Crank is a rotating part, Which is either a hand driven or motor driven.	Mild steel	Ø210mm
3	Slotted bar has a slot in which the crank pin engages or slides over it.	Mild steel	185x 65x25mm
4	Crank pin is welded on a crank at a pitch circle diameter (PCD) of 130 mm.	Mild steel	Ø25 mm and 70mm length
5	Shaft is a rotating machine element, which is used to transmit the torque. One end of the shaft is connected to the handle slot and other end of the shaft is welded to the centre of the crank disc.	Steel	Ø30 mm and 200 mm length
6	Connecting rod is used to connect the slotted bar to the cutting tool on either sides of the bar. The connecting rod is supported at the frame.	Mild steel	Ø15 mm and length 450mm
7	Plummer block is used for holding rotating shafts with help of bearing and other parts.	Brass	Ø30 mm

International Journal of Innovative Research in Science, Engineering and Technology

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Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

8	Cutting tool is a tool that is used to remove material from the work piece by means of shear deformation. Cutting tool must be stronger than work piece. In shaper machine the cutting tool moves in a direction normal to the work piece. Ex: High speed steel, carbon steel, carbides, etc. The cutting tool material must have the properties such as high hardness and strength at high temperature, good toughness and high tool life.	High Speed Steel(HSS)	-
9	Nut is a hollow material where bolts are inserted.	Mild steel	Ø6 mm
10	Bolt is moved inside nut. It has head, shank, thread portion.	Mild steel	Ø10 mm

Various components of dual side shaper are discussed below:

Operations done for manufacturing shaping machine:

- Cutting
- Turning and facing
- Milling
- Drilling and tapping
- Fillet and chamfering
- Welding
- Grinding and assembling.

III. WORKING

Shaper is the metal cutting machine tool designed for cutting flat work piece by a tool. Shaping is used to machine thin and soft plates. The operation of machine is simplified to few simple operations involving a motor and tool head arrangement. When the crank is driven by a motor or by handle, the crank rotates about the axis, so the crank pin slides inside the slot of the slotted plate. As the crank rotates, the slotted bar reciprocates due to the sliding of crank pin. The connecting rod attached with the slotted plate on both sides, reciprocates as the crank rotates. The cutting tool is attached at the both sides of connecting rod, to carry out the cutting operation. Since the cutting tool is placed on both sides, operation can be done at both the sides of the machine i.e. the return stroke at one end is converted into cutting stroke at the other end, thereby it reduces the production time and increases the Metal removal rate (MRR).

International Journal of Innovative Research in Science, Engineering and Technology

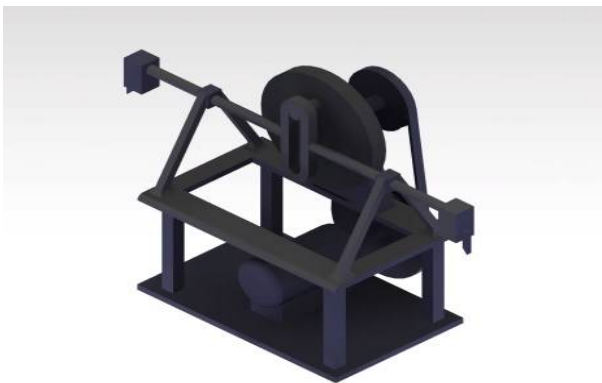
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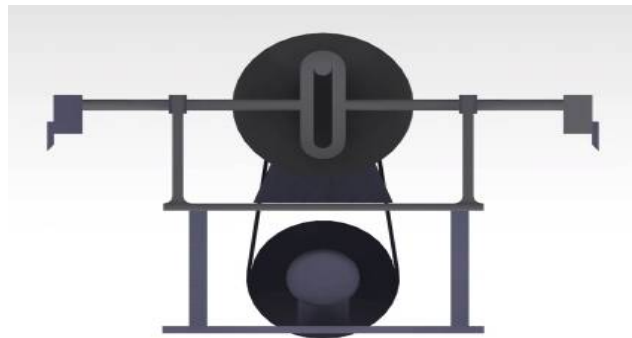
Vol. 6, Issue 7, July 2017

IV.ASSEMBLED VIEW

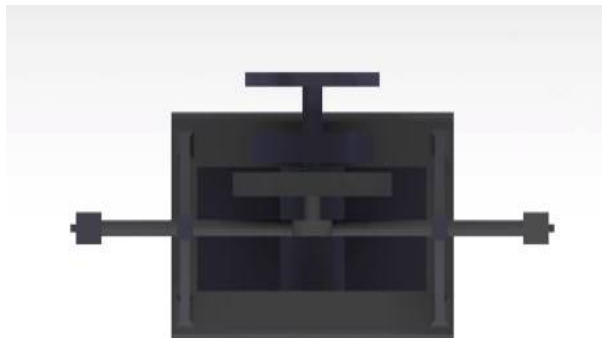
Various views of dual side shaper are shown below:



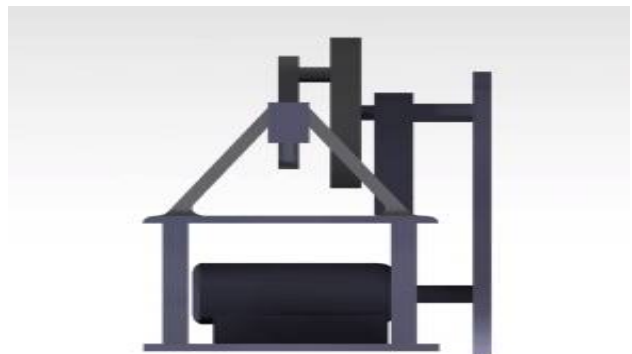
(a)Isometric View



(b)Front View



(c)Top View



(d)Side view

V.DESIGN CALCULATION

1. Design Parameters:

Diameter of Crank = 0.21m.
Length of slotted bar = 0.185 m.
Length of connecting rod= 0.45m.

2. Cutting Force:

Assume,
Power = 736 Watts
Speed = 200 RPM

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

$$P = \frac{2\pi NT}{60}$$

$$T = 35.159 \text{ Nm}$$

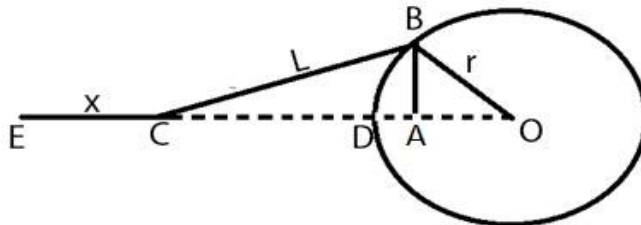
We Know that,
Torque = Force X Radius of crank
 $F = 296.75 \text{ N}$

3. Design of Shaft:

Diameter of the shaft = 0.03 m
Permissible shear stress for mild steel = 34 N/mm²
 $T1 = \pi/16 * (f_s) * d^3$
 $35.159 = \pi/16 * (f_s) * 0.03^3$
 $F_s = 6635338.5 \text{ N/m}^2$
 $F_s = 6.635 \text{ N/mm}^2 < F_{s(\text{permissible})} = 34 \text{ N/mm}^2$
Therefore, the design is safe.

4. Cutting Stroke Calculations:

Scotch yoke mechanism:



Let 'X' is the length of the cutting stroke
 $X = OD + DE - AC - OA$
r – Radius of the Crank.
L – Length of the link AB.
Angle AOB = θ
Angle ACB = Φ

In triangle ABC,
Cosine $\Phi = AC/L$
 $AC = L \cdot \cos \Phi$
In Triangle OAB, Cosine $\theta = OA/r$
 $OA = r \cdot \cos \theta$
Sine $\Phi = h/L$ Sine $\theta = h/r$
Cosine $\Phi = \sqrt{1 - \text{Sine}^2 \Phi}$

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

$$= \sqrt{1 - (r^2 \sin^2 \theta / L^2)}$$

$n = L / r$ = connecting rod length/Crank radius

$$\cos \phi = [1 - (\sin^2 \phi / n^2)]^{1/2}$$

If $n \gg 1$, by binomial expansion $\cos \phi = 1 - (\sin^2 \phi / 2n^2)$

$$X = r + L - L [1 - (\sin^2 \theta / 2n^2)] - r \cos \theta$$

$$X = r (1 - \cos \theta) + L [1 - 1 + (1 - \cos 2\theta) / 4n^2]$$

$$X = r (1 - \cos \theta) + r^2 / 4L (1 - \cos 2\theta)$$

Velocity:

$$V = dX / dt = \omega r (\sin \theta) + r / 4L (2 \sin 2\theta)$$

Acceleration:

$$a = d^2x / dt^2 = r \omega^2 (\cos \theta + r / L (\cos 2\theta))$$

Assume, Radius of the crank, $r = 105$ mm

Length of the CR = 450 mm

$$\text{At } \phi = 0, \theta = 0$$

$$X = 450 + 105 = 555 \text{ mm}$$

$$\text{At } \phi = 0, \theta = 180^\circ$$

$$X = 450 + 105 + 0 - 100 \cos 180 = 555 \text{ mm}$$

$$\begin{aligned} \text{The length of the cutting stroke} &= 555 - 450 \\ &= 105 \text{ mm} \\ &= \underline{10.5 \text{ cm}} \end{aligned}$$

5. Cutting Speed:

$$\text{Cutting speed, } v = N L (1+m) / 1000 \text{ m/min}$$

N = the number of double strokes or cycles of the ram per min (take $N = 100$)

L = Length of the ram stroke in mm

m = return stroke time/cutting stroke time, $m = 1$

$$v = \underline{0.021 \text{ m/min}}$$

VI. ANALYSIS

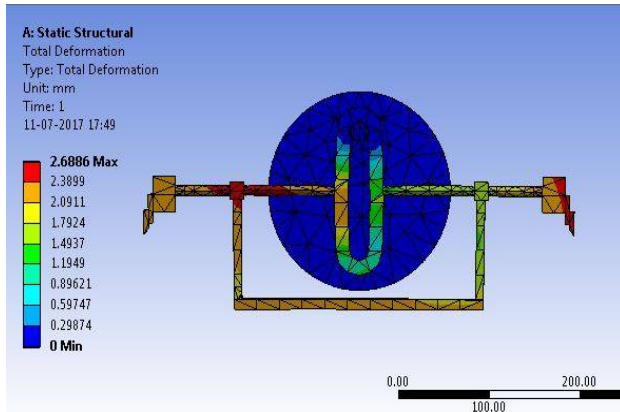
Analysis is detailed evaluation of a particular model to identify places for improvement and make respective changes if needed. This includes collecting an industrial requirement and researching to satisfy their requirements. The main motto of analysis is that it increases reliability and efficiency to the product. Analysis mainly concentrates on cost, flexibility, controls, risk, quality etc. Maximum deformation and maximum principle stresses are obtained at slotted bar. Deformation occurs at cutting tool due to progressive action of cutting. Cutting deformation is based on previously calculated cutting force i.e. 296.75N. Maximum deformation and maximum principle stress is based on materials of crank disc, slotted bar and also the cutting speed i.e. 0.021m/mins.

International Journal of Innovative Research in Science, Engineering and Technology

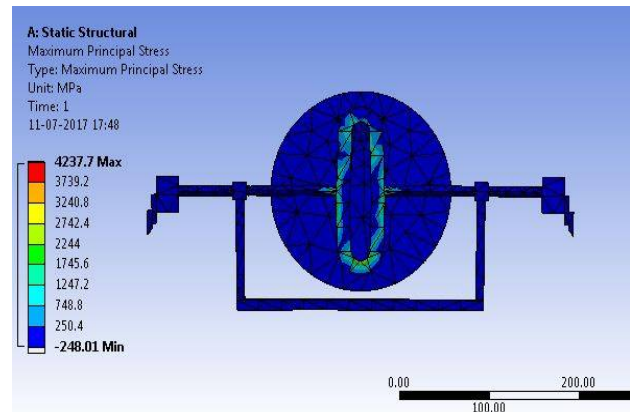
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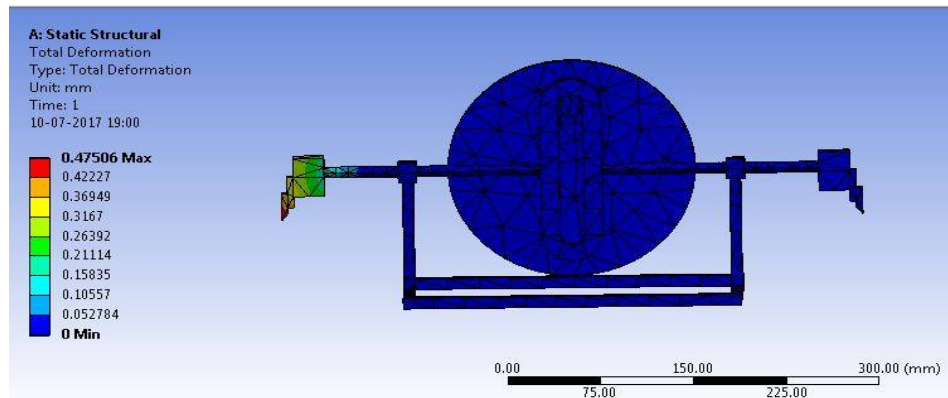
Vol. 6, Issue 7, July 2017



(a) Total deformation on slotted bar



(b) Maximum Principal Stress on slotted bar



(c) Total deformation on cutting tool

In a slotted bar, points that are in contact with crank pin experiences more deformation and stress when compared to other points. Deformation on cutting tool is analysed on one side only because removal of materials is carried at only one side at a time. Analysis of our shaper machine is carried out with our above specified materials. Overall analysis of our shaper machine is satisfactory and can be used in industries for efficient production.

VII.CONCLUSION

We have designed a dual side shaper with appropriate dimensions and analysed various properties for a cutting tool (Shaper tool) using scotch yoke mechanism. We have applied various rapid wear of the slot in the yoke caused by sliding friction and high contact pressures. This wear can be reduced or controlled by maintaining lubricant near yoke. Scotch yoke mechanism plays an important role in shaping, planning, and slotting machine. This Mechanism is also used in scotch yoke engines. This can also be used in valve actuators in high-pressure oil and gas pipelines. It has been used in various internal combustion engines, such as the Bourke engine, SyTech engine, and many hot air engines and steam engines. It is best suitable for machining brittle materials like iron, copper, zinc etc

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Vol. 6, Issue 7, July 2017

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